INSECT RESPONSES TO COLORS

By Harry B. Weiss

The purpose of this article is to call attention to the approximately similar qualitative results obtained by various workers who used widely different methods of approach and technique in studying the behavior of insects to different wave lengths of light. No attempt will be made here to describe the techniques, as they are already matters of record. In fact they differ as widely as the methods of approach.

Bertholf (1, 2) exposed the honey bee, and the fruit fly Drosophila to two translucent glass plates of equal size, one illuminated with white light and the other with monochromatic light obtained by means of a quartz prism. The intensity of the white light was changed until its effect on the photopositive response of the insects was equal to that of monochromatic wave lengths in different portions of the spectrum. He found that for the honey bee, the stimulating efficiency increased from zero at 6450 Å to a maximum of 100 arbitrary units at 5500 Å, then decreased to 10 at 4350 Å after which it rose rapidly to a second maximum of 450 at 3650 Å and then rapidly declined to zero at about 2800 Å.

As for Drosophila, Bertholf (2) stated ". . . starting with the longer wave lengths the efficiency is very low until it starts to rise at about 5750 Å; from here it rises to a maximum in the so-called visible spectrum at 4870 Å . . . ; from this wave length it decreases again at 4250 Å; then it rises suddenly and attains a maximum value at 3650 Å . . . ; from here it decreases rapidly to zero at 2540 Å." Bertholf worked with 30 wave lengths from 2300 Å to 7000 Å.

Weiss *et al.* (6, 7, 8) exposed approximately 15,000 insects, both adult and larval forms, mostly diurnal, but some nocturnal, involving 40 species in various orders to 10 wave-length bands of light of equal physical intensities from 3650 Å to 7400 Å. Each test lasted from 15 to 30 minutes and a group of 100 or more of each species was used for from one to three successive tests. The composite group behavior pattern, both for larvæ and adult insects indicated that the stimulating efficiency increased only slightly from zero at 7200 Å to 5750 Å. From here it rose to a maximum at 4920 Å. It then declined to a comparatively low level at 4640 Å from which point it ascended to its peak maximum level at 3650 Å.

These authors found that, regardless of the relative positions of the wave-length bands, the insects made approximately the same selections time after time, also that when a second and third test followed the first, there was a shifting of individuals that went to the different colors, but no change in the final result. In addition some species such as the Japanese beetle and the Colorado potato beetle responded to what were unattractive wave lengths under equalized physical intensities, when the intensities of such unattractive wave lengths were increased. In other words, it was possible to vary the behavior pattern by varying the intensities.

Crescitelli and Jahn (3), approached the problem from the standpoint of the electrical responses of the dark-adapted grasshopper eye. "Leads were taken with silver-silver chloride electrodes from fluid-filled chambers about each eye. The entire surface of one eye was illuminated, and the other eye was kept in darkness. Records were obtained by means of a cathode ray oscillograph. For the experiments on colored light Corning color filters were placed between the light source and the eye." Six wave-length bands were employed, extending from about 4000 Å to 7000 Å. "The relative intensity transmitted through each of these six filter combinations was determined by means of a thermopile and galvanometer. The infra-red radiations were completely removed from the stimulating light by using 5 cm. of water and a Corning (AKLO) heat absorbing filter."

These authors studied the change in form of the electrograms of the grasshopper eye under variations in intensity of the stimulating light and also the quantitative aspects of the response in relation to the quality of the stimulating light. They found that there was apparently no specific effect of wave length on the electrical response of the whole dark-adapted grasshopper eye. At equalized intensities there were decided differences in wave form with the six different spectral bands, but these disappeared and the color responses were exactly matched when the intensities of the different spectral regions were properly adjusted. Quoting again from their paper: "The form of the electrical response of the dark-adapted grasshopper eye to brief stimulation by white or colored light varies according to the intensity of the light. At very low intensities the response is diphasic, the initial positive phase of which resembles the a-wave of the vertebrate electroretinogram. As the intensity is increased the positive phase decreases and changes its position while the negative phase becomes increasingly prominent. Eventually the positive phase is completely eliminated and the electrogram takes the form of the typical high-intensity response. The order of effectiveness of the different colors in causing this change in wave form is: green, blue, violet, orange-red, red."

The curve relating the magnitude of the potential to the wave length had a peak in the green region of the spectrum, and declined sharply toward the red and less sharply toward the violet. The magnitude of the electrical response was found to be definitely related to the quality of the stimulating light and the form of the response to be influenced by the intensity of the stimulating light, either white or colored.

Jahn and Crescitelli (5), also studied, in the same manner, the electrical responses of the compound eye of the moth *Samia cecropia*, in relation to the quality and intensity of the stimulating light. Part of their conclusions are quoted as follows: "The electrical responses of the moth and grasshopper eyes to wave length are surprisingly similar. For both animals the same type of graph is obtained when the relative magnitude of the potential is plotted against wave length. This graph has a general similarity to the absorption curve of visual purple. Another aspect of the electrical response to wave length concerns the fact that no specific effects of wave length on the electrograms are discernible. By properly adjusting the intensity, the responses to one color may be exactly matched with the response to any other color, indicating that the differences in the responses to different colors of equal intensity are caused merely by differences in sensitivity and are not effects of wave length *per se*."

In the case of the moth eye the maximum response was obtained with the green band. The responses dropped sharply toward the red band and less sharply toward the violet.

Graham and Hartline (4) studying the responses of single visual sense cells of Limulus to visible light of different wave lengths found that when the energy of the stimulating light of different wave lengths was approximately equal, the response to green was stronger than the responses to either violet or red. When the energy was increased in the red and violet their level of response was raised and when the intensities of the different wave lengths were adjusted so that the responses were equal, there was no effect of wave length as such, indicating that single sense cells can gauge brightness, but cannot distinguish wave length. The relative energies of the various wave lengths required to produce the same response, after being adjusted in inverse ratio to the degree of their absorption yielded a visibility curve for a single visual sense cell that had its maximum in the green near 5200 Å and that declined symmetrically on each side to low values in the violet near 4400 Å and in the red near 6400 Å.

Thus the visibility curves of a single visual sense cell of Limulus, although not an insect, of the eye of a grasshopper, a diurnal insect, and of the eye of a Cecropia moth, a nocturnal insect, are qualitatively similar to the curve of the relative stimulating efficiency of different wave lengths of light for Drosophila, as reported by Bertholf and to the behavior curves for the numerous adult and larval forms of diurnal and some nocturnal insects as reported by Weiss *et al.* These curves are not identical because of the different methods of approach and technique but they are all strikingly similar for the visible portion of the spectrum. All were obtained under wave lengths of equalized physical intensities. Hartline and Graham and Crescitelli and Jahn by properly adjusting the intensity were able to match the response to one color with the response to any other color and Weiss *et al.*, in their behavior studies found that insects responded to what were unattractive colors under equalized intensities, when the intensities of these colors were increased.

Crescitelli and Jahn (3) report that other authors who worked with pigeon eyes and the eyes of certain vertebrates also found that wave form difference are simply intensity differences and that the electrical response to different wave bands could be duplicated by adjusting the intensity of the different bands.

Thus it appears that both the electrical responses of the insect eye and the motor responses of the insect itself to different colors of equal intensity are due to differences in sensitivity, or to the absorption of light, which varies with wave length, by the primary photosensitive substance of the visual sense cells, and are not the effects of wave length by itself.

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